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Postharvest conservation of 'Sunrise Solo' papaya under cassava starch coatings added with ginger essential oil

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Abstract

The use of biodegradable coatings associated with essential oils with fungicidal action can be an efficient alternative in the conservation and reduction of postharvest losses of papaya, a very perishable fruit susceptible to decay. In this sense, the objective of this work was to evaluate the postharvest conservation of papaya under cassava-based starch biodegradable coatings, added with essential oil (EO) of ginger. The experimental design was the completely randomized in a split-plot scheme, with the plot consisting of 5 coatings applied to 'Sunrise solo' papaya' harvested in the light green maturity stage: (control (without coating); 2% cassava starch (S2%); S2% + 0.15% ginger essential oil (EO); S2% + 0.30% EO and S2% + 0.45% EO) and in the subplot the days of storage: (0, 3, 6, 9 and 12 days), with 4 replications. Papaya coated with S2% + 0.30% EO showed a delay in color evolution, lower weight loss, maintained the levels of soluble solids and ascorbic acid, in addition to reducing the incidence of decay and increasing the purchase intention, thus increasing postharvest life in 4 days as related to control fruits. The use of 2% starch coating added with 0.30% ginger essential oil is a viable, sustainable and low-cost alternative for maintaining the quality and adding value to 'Sunrise solo' papaya as a clean technology.

Keywords: *Manihot esculenta* Crantz, biodegradable coating, clean technology, *Zingiber officinalis* (Willd.) Roscoe, decay

Introduction

Papaya is a fruit widely traded and consumed worldwide, as it is rich in calcium, vitamin A and C, which in addition to a much appreciated taste makes it widely used in diets (Reis et al., 2015; Pan et al., 2017). As it has recognized health benefits, the interest in this fruit has increased continuously, especially for fresh consumption, as well as minimally processed or in the form of juices, nectar, sweets and other products (Bautista-Baños et al., 2013).

However, one of the problems of climacteric fruits, such as papaya, is the short shelf life (Ayón-Reyna et al., 2017), whose high metabolic rate results in high postharvest losses (Zerpa-Catanho et al., 2017). Thus, softening and high incidence of rot are the main factors that reduce the quality of papaya (Pan et al., 2017). Therefore, ripening control is extremely important to maintain quality and increase postharvest useful life of this fruit (Façanha et al., 2019).

One of the current strategies for controlling ripeness, as well as maintaining postharvest quality of fruits and vegetables, is the use of biodegradable coatings. Studies focused on the use of these approaches are of fundamental importance, both ecological and economical, since the synthetic materials used in postharvest are generally high costly and use chemicals that are harmful to the environment and potentially to health (Alikhani, 2014). These coatings can be made from renewable raw materials, with wide regional availability, such as cassava (Lima et al., 2012; Azerêdo et al., 2016) and fruit seeds (Rodrigues et al., 2018), which are applied directly to the fruits, forming thin membranes, with structural characteristics that depend on the formulation and preparation procedure adopted (Basiak et al., 2019). In this direction, the use of starch-based coatings added with essential oils represents a promising

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strategy in reducing microbial growth and enhancing the postharvest conservation of fresh (Guimarães et al., 2017) and minimally processed fruits, which can increase their added value (Kalia & Parshad, 2014), since this is currently recognized as a clean technology (Jabeen et al., 2015).

Ginger (*Zingiber officinalis* (Willd.) Roscoe) is grown worldwide for medicinal purposes. The main compounds found in its essential oil were gingerol, zingerone, β-zingiberene, 1,8-cineole+limonene+β-phellandrene, geraniol, neral, β-bisabolene and β-sesquiphellandrene, all with strong inhibitory action on the growth of fungi and bacteria (Mahboubi, 2019). Although extracts of *Z. officinales* have been used to control plant diseases (Chiejina & Ukeh, 2012), there are no data on adding its essential oil on starch-based matrices coatings to prevent postharvest decay.

In this sense, this study aimed to evaluate the postharvest conservation of 'Sunrise solo' papaya during storage under cassava starch-based biodegradable coatings added with different levels of ginger essential oil.

Material and Methods

Fruits of 'Sunrise solo' papaya (*Carica papaya* L.) were harvested early in the morning from a producer area, in the maturity stage with a light green color and soon transported do the laboratory for the experiment procedures.

The experiment was carried out in a completely randomized design in a split-plot scheme, with 5 coatings applied to the papayas: [fruits without coating (control - (Cont); 2% (S2%) cassava starch; S2% + 0.15% ginger essential oil (EO) (S2% + 0.15% EO); S2% + 0.30% EO and S2% + 0.45% EO], and in the subplot the storage periods: (0, 3, 6, 9 and 12 days), with four replications of 2 fruits/tray.

For setting the experiment, in the laboratory fruits were washed with fresh water, sanitized in sodium hypochlorite solution at 50 ppm for 15 minutes and air dried. Following, the fruits were transferred to a cold chamber at 12 °C for 6 hours, to remove heat from the field. For application of the coatings, the fruits were immersed in the coating solutions for 1 minute and dried in the air for 3 hours, then placed in expanded polystyrene trays, identified and stored under room condition (24 ± 2 °C and 75 ± 3% RH).

In preparing the coatings, the cassava starch (*Manihot esculenta* Crantz) was extracted and gelled according to Lima et al. (2012). 2% (S2%) of cassava starch (17% moisture) was used, which was dissolved in fresh water (w/w) and then heated under constant stirring to 70 ° C. After cooling to 30 °C, specific levels of essential oil (EO) of ginger (*Zingiber officinalis* (Willd.) Roscoe) were added under stirring to each coating solution, to which fixed levels of Tween 40® (0.1%). mL L^{-1}) and glycerol (1.0% mL L^{-1}) were added, the first being used to improve homogenization, and the second, to maximize plasticization properties (Salvia-Trujillo et al., 2015). After preparation, each coat was left to cool at room conditions and then applied to the fruits.

Fruits from all coatings were room stored for 12 days and evaluated at 3-day intervals, with respect to the following variables: weight loss, using the semi-analytical scale (%) taking the day zero as reference, according to Guimarães et al. (2017); the firmness of the fruit (N) was determined at two different points in the median region of the intact fruits, using a Magness Taylor® Pressure Tester Penetrometer (Drill Press Stand, Canada); the color of the peel and pulp was determined using a Minolta® colorimeter, using the parameters: L^* (clarity/luminosity); a^* (transition from green ($-a^*$) to red ($+a^*$)) and b^* (transition from blue ($-b^*$) to yellow ($+b^*$), the farther from the center (= 0), more saturated the color. Followed the transformation of the readings, the color index (CI) was calculated, which indicates the degree of green to yellow variation of the samples, according to the equation proposed by Camelo & Gomes (2004). The color difference of the pulp and peel (ΔE) was calculated according to the evolution of the storage periods.

The content of soluble solids - SS (%) was determined with a digital refractometer with the readings adjusted to 20 °C. The titratable acidity -AT (citric acid. 100 g^{-1} pulp) was measured by titrating the juice with 0.1 M NaOH solution; the pH was measured using a bench pH meter; the SS/TA ratio was obtained by dividing the SS by TA contents (IAL, 2008). The ascorbic acid content (mg 100 g^{-1} of pulp) was determined by titration with a solution of 2.6 dichloro-phenol-indophenol at 0.02% (Strohecker & Henning, 1967).

The sensory attributes were evaluated by means of a sensory panel composed of 18 trained panelists using a 9-point hedonic scale (Meilgaard et al., 2006). The extremes for color uniformity were "very uneven" (1) and "very uniform "(9); for the purchase intention "I would certainly buy" (9) and "I certainly would not buy" (1); and for general appearance, "I disliked a lot" (1) and "I liked it a lot" (9). At each storage period, disease was also evaluated as incidence of decay (%) from 0 to 4, where: 0 = 0% of fruit surface rotten, 1 = 1–5%, (initially damaged), 2 = 6–15% (lightly damaged), 3 = 16–30% (moderately damaged), 4 = >31% (severely damaged), based on Bosquez-Molina et al. (2010).

The data were tested for normality and subjected to analysis of variance, with a regression test applied to the storage periods and the means compared by the Tukey test at 5% probability. Additionally, multivariate correlation tests were performed by color scale and also principal component analysis, comparing the effect among physical, physicochemical and sensory analyzes, using JMP® and SISVAR® software.

Results and Discussion

The weight loss of the fruits (Figure 1A) showed a significant interaction between storage periods and coatings. Control fruits showed greater weight loss, with 18% at the end of storage. Coated fruits, mainly those with 2% starch (S2%), S2% plus 0.30% ginger essential oil (EO) (S2% + 0.30% EO) and S2% + 0.45% EO, showed lower weight losses, with 13.19, 13.04% and 12.92%, respectively, after 12 days storage, indicating lower permeability to water vapor (Khademi & Ershadi, 2013) and, therefore, the efficiency of these coatings in reducing water losses.

That was also possibly that the coatings applied provided a decline in the metabolic rate that resulted in a reduction of the transpiration rate (Pareek, 2016), minimizing, thus, the losses of water. Azerêdo et al. (2016) also reported lower weight losses in mangoes coated with starch added with fennel essential oil compared to control.

Fruit firmness (Figure 1B) decreased during storage, but did not differ among the coatings applied, declining from 46.21 N to 6.46 N (approximately 86%), during the 12 days in room storage. Façanha et al. (2019), shown this marked loss of firmness in 'Golden' papaya postharvest. This quick loss of firmness in papaya is directly related to degradation of cell wall oligosaccharides, through an increase of activity of the polygalacturonase, endoxylanase, pectinesterase (Zerpa-Catanho et al., 2017), which are tight regulated by ethylene (Pareek, 2016).

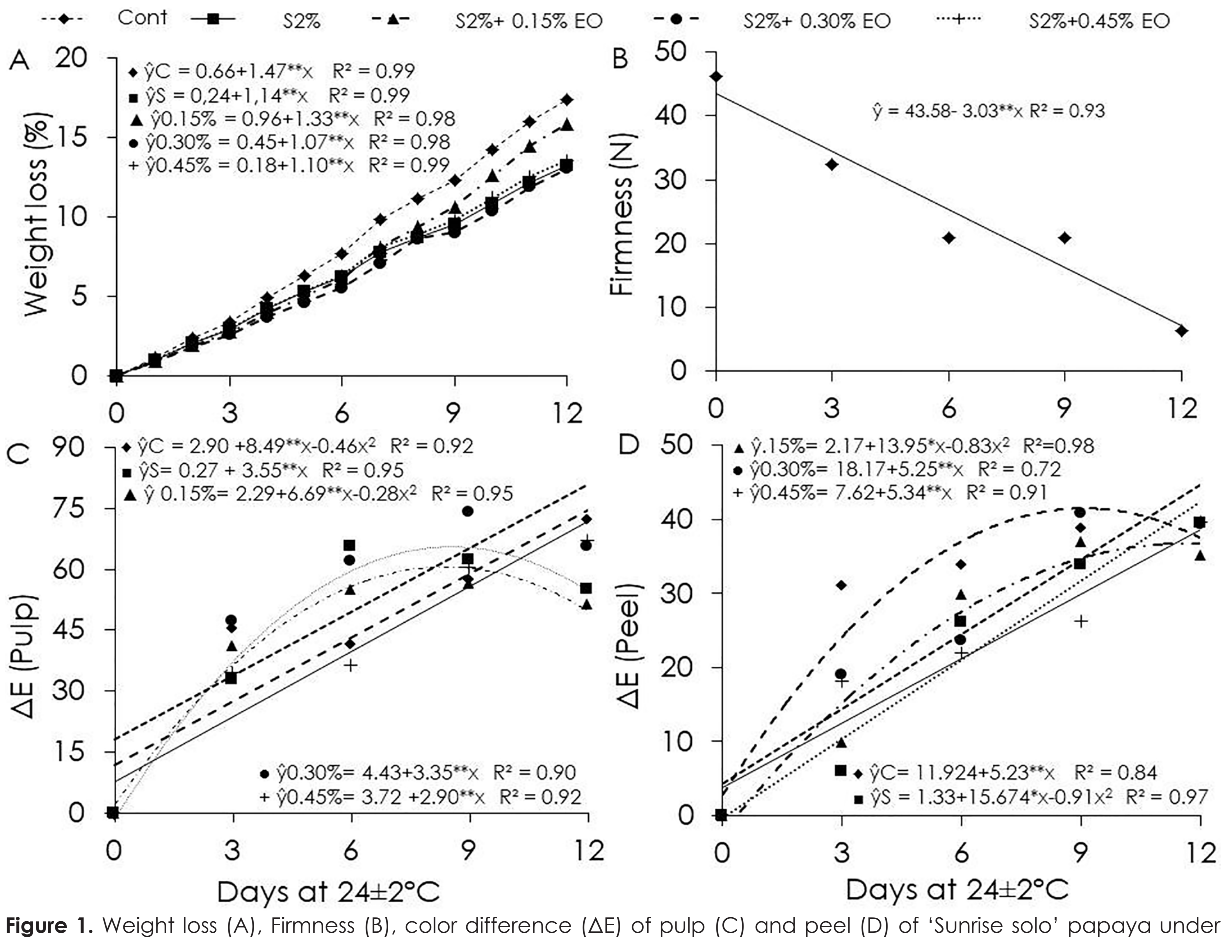

Figure 1. Weight loss (A), Firmness (B), color difference (ΔE) of pulp (C) and peel (D) of 'Sunrise solo' papaya under 2% cassava starch-based biodegradable coatings added of ginger essential oil (EO) and control (Cont) during room storage (24 ± 2 °C and 75 ± 3% RH). n=4.

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For the color difference (ΔE) of the pulp and peel, interaction among treatments and storage periods was observed (Figure 1C and D). The color difference in the pulp (Figure 1C) of the control, S2%, S2% + 0.15% EO fruits reached maximum values at the 9th day of storage at room conditions, then declining. In turn, in papayas coated with S2% + 0.30% EO and S2% + 0.45% EO o ΔE of the pulp continued to increase until the 12th day of storage, indicating a slower evolution of ripening (Pareek, 2016). The color difference (ΔE) of the peel was less intense than the pulp (Figure 1D), but presented a similar behavior to that of the pulp, with maximum value on the 9th day of storage for control fruits, S2% and S2% + 0.15% EO, in that order, then declining. Also for the peel, fruits coated with S2% + 0.30% EO and S2% + 0.45% EO kept the ΔE rising, confirming the action of these coatings in delaying ripening.

The peel color index (Figure 2) determined the changes from green to yellowish tones, followed by orange color in 'Sunrise Solo' papaya, as a result of chlorophyll degradation, followed by the synthesis / uncovering of carotenoids, with clear indicative of evolution or delay of ripening (Zerpa-Catanho et al., 2017).

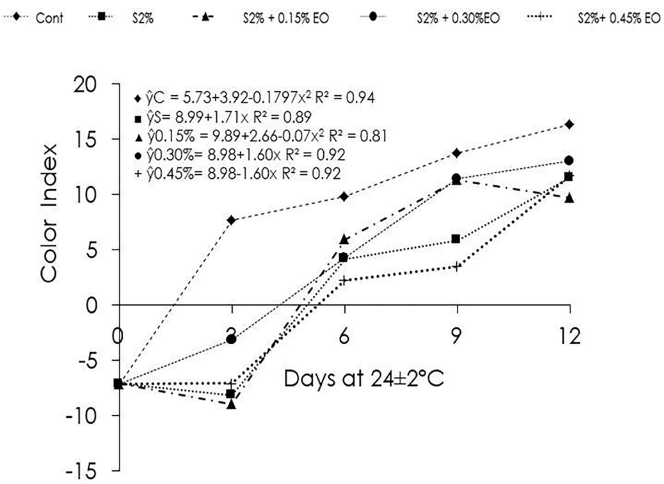

Figure 2. Color Index of 'Sunrise solo' papaya under 2% cassava starch-based biodegradable coatings added of ginger essential oil (EO) and control (Cont) during room storage (24 ± 2 °C and 75 ± 3% RH). n=4.

Control fruits (without coating), showed a rapid transition from green to yellowish color after the 1st day of exposure to room conditions, while in coated fruits this transition was observed after the 5th day of storage, indicating delay in ripening, as also reported in mango (Azerêdo et al., 2016) and guava (Rodrigues et al., 2019), herein much evident in those coated with S2% + 0.45% EO. The color of the peel is the attribute most used to determine the evolution of the maturity stages of fruits (Maqbool et al., 2011).

A significant effect was observed for soluble solids (SS) (Figure 3A) among storage days and coatings. Control papayas showed faster evolution in SS, reaching the maximum (15.3%) on the 6th day of storage and contents well above those of coated fruits. The increase in the soluble solids content can be attributed to the accumulation of soluble sugars due to the hydrolysis of starch and partially to the release of sugar residues from the degradation of the pectic polysaccharides of the cell wall (Façanha et al., 2018) processes that occur during the ripening of fruits (Pareek, 2016).

Fruits coated with S2% + 0.30% EO and S2% + 0.45% EO showed lower SS levels, varying between 10 and 12%, indicating a reduction in the metabolic rate, thus delaying ripening, as for guavas (Rodrigues et al., 2019). Reis et al. (2015), reported in mature papayas of the Solo line mean levels of SS ranging from 9.58 to 14.73%, close to the levels found in the fruits in here.

For titratable acidity (TA), no significant interaction was observed between coatings and storage days. However, TA, normally very low in papaya lines (Reis et al., 2015), decreased during storage (Figure 2C).

The SS/AT ratio of 'Sunrise Solo' papaya was affected by the coating applied to the fruits (Figure 3C). Control fruits and those coated only with S2% showed superior SS/AT ratios, higher than 190, which differed from the others. Papaya coated with S2% + 0.15% EO, S2% + 0.30% EO and S2% + 0.45% EO showed averages of 168.78 and 170.16, respectively, with the latter having the lowest value, 157.21. The SS/TA ratio of papaya is generally very high due to the low levels of TA, which characterizes this fruit as having a very sweet taste. The values of the SS/AT ratio are in the range reported by Reis et al. (2015).

The ascorbic acid (AA) content suffered a significant effect between coatings and storage periods (Figure 2B). The AA content increased during storage and was higher for control fruits, whose maximum content was reached on the 9th day, followed by a decline. Fruits coated with S2% + 0.15% EO showed a maximum AA content in the 6th and then declined. In turn, fruits coated with S2% + 0.30% EO and S2% + 0.45% EO showed a continuous increase in AA levels, as an indication that these coatings reduced the metabolic rate and, therefore, delayed ripening. Similar behavior for AA was reported by Rodrigues et al. (2019) in guava.

Regarding the sensory attributes, for color uniformity (CI) (Figure 4A) papayas from the control, and coated with S2% and S2% + 0.15 EO showed greater uniformity, with the control reaching its maximum on the 6th day of storage followed by decline, in the perception of the panelists. In papayas coated with S2% + 0.30 EO, a slower but consistent evolution of CI was reported in here during maturation. In turn, in fruits coated with S2% + 0.45 EO, although the color evolved more slowly, it was perceived as uneven, indicating that the ripening, although slower, was compromised by the higher level of OE in the starch matrix. The impairment of ripening due to the increase in EO levels in the matrix was also reported by Lima et al. (2012) in Tommy Atkins mangoes.

Despite the greater color uniformity, the control fruits obtained much higher incidence of decay (ID) scores, compared to coated fruits, which evolved from fruits with no decay (score 0) on the 1st day of evaluation, to score 4 => 31% (severely damaged) (score 4) on the 12th day of room storage (Figure 4B). In turn, papayas coated with S2% + 0.15% EO and S2% + 0.30% EO in the 9th day were reported as in score 2 (6–15% of ID (lightly damaged), with a clear indication of the effectiveness of these coatings in postharvest conservation of these fruit.

For purchase intent (PI), papayas coated S2% + 0.30% EO were perceived as above the acceptance line due to the lower incidence of blemishes and apparent diseases, with the fruits of control having exceeded the PI limit on the 5th day of room storage. The positive effect of adding lower levels of EO was also perceived by panelists in the postharvest conservation of 'Pérola' pineapple (Guimarães et al., 2017) and mango (Lima et al., 2012; Azerêdo et al., 2016). Thus, adding 0.30% ginger EO provided an increase in 4 days in the postharvest life of papayas (Figure 4C).

For the general appearance (GA) attribute, fruits of the control were rejected by the panelists on the 5th day of storage (Figure 4C). In turn, the GA of papayas coated with S2% + 0.45% EO was reported in here as compromised by the presence of spots, decay, uneven ripening, and indications of physiological disorder resulting from the highest level of the EO. However, in accordance with PI, better scores were also received for fruits coated with S2% + 0.30% EO, notably for greater brightness, lower dehydration and ID, apparent damages and uniform ripening, also maintaining above the acceptance limit for 9 days, which mean 4 more days as compared with the control fruits. This, all together, proves the greater effectiveness of this coating in postharvest conservation of papaya.

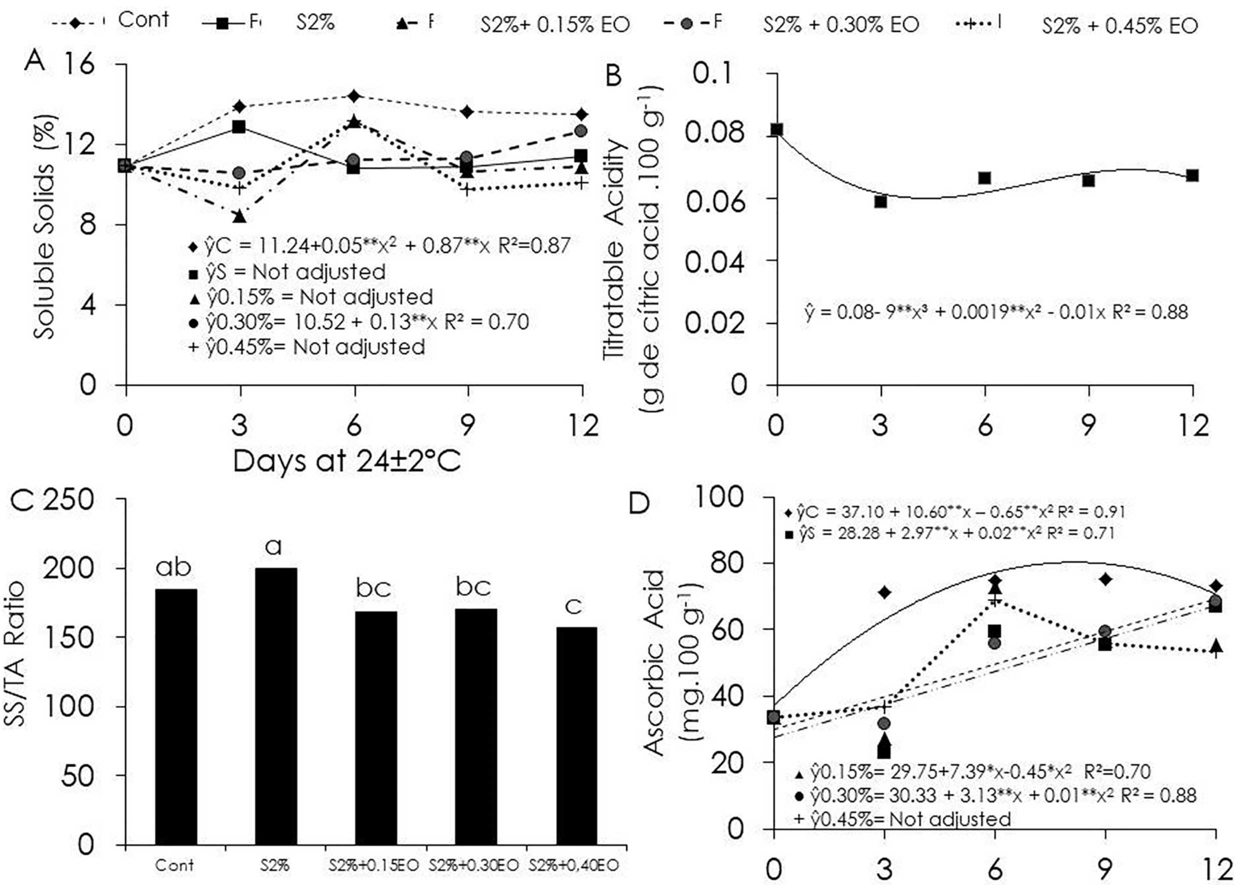

Figure 3. Soluble Solids – SS (A), Titratable Acidity - TA (B), SS/TA Ratio (C) and Ascorbic Acid (D) of 'Sunrise solo' papaya under 2% cassava starch-based (S2%) biodegradable coatings added of different levels of ginger essential oil (EO) and the control (Cont), during room storage (24 ± 2 °C and 75 ± 3% RH). Bars with different lowercase letters indicate difference between treatments, using the Tukey test at 5% probability. n=4.

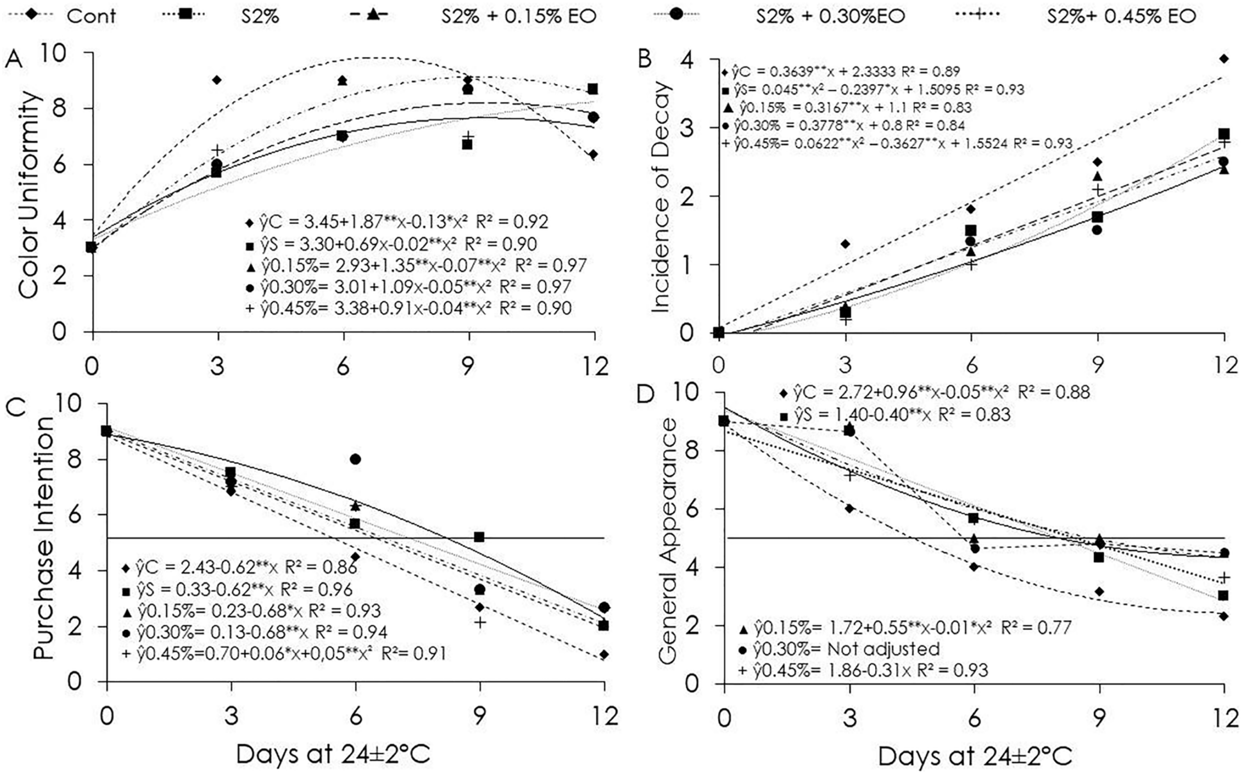

Figure 4. Sensory attributes of color uniformity - CI (A), incidence of decay - ID (B), purchase intention - PI (C) and general appearance - GA (D) of 'Sunrise solo' papaya under 2% cassava starch-based (S2%) biodegradable coatings added of different levels of ginger essential oil (EO) and the control (Cont), during room storage (24 ± 2 °C and 75 ± 3% RH). n=4.

In the principal component analysis (PC) (Figure 5A), two components discriminated 84.4% of the variance, forming 3 groups (Figure 5 A). PC 1 explained 71.4% of the variance, which strongly grouped the variables with the highest values of fruits without coating (control), due to the higher levels of WL, ΔE Peel, SS, CI, AA, CU and ID.

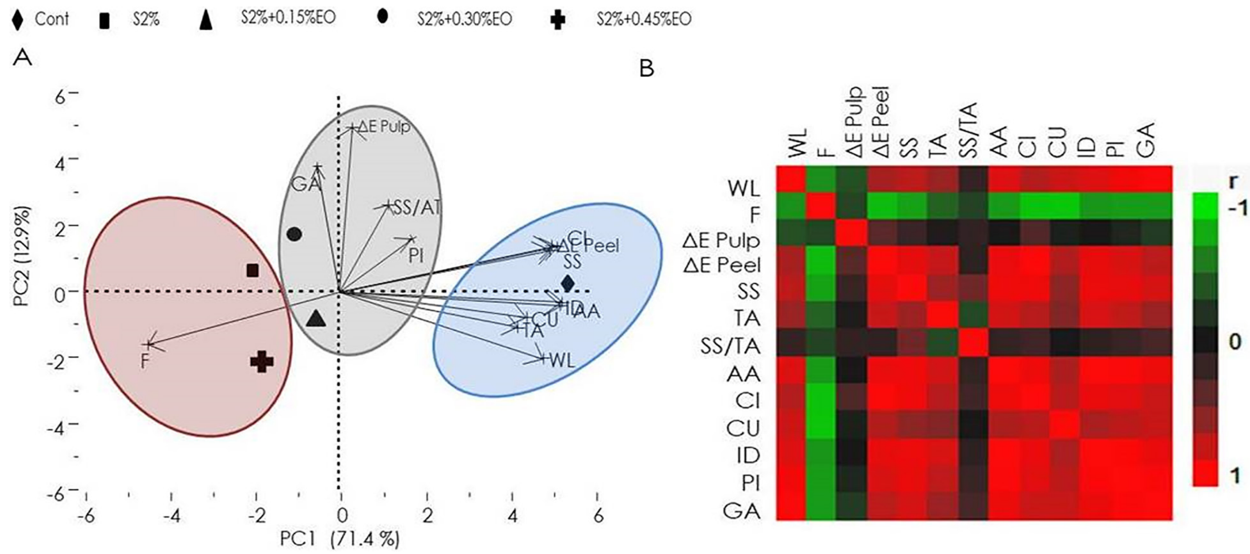

Figure 5. Principal components analysis (A) of the physical, physicochemical and sensory attributes of 'Sunrise soil' papaya of 'Sunrise solo' papaya), stored at room conditions (24 ± 2 °C and 75 ± 3% RH) under 2% cassava starch-based (S2%) biodegradable coatings added of different levels of ginger essential oil (EO) and the control (Cont), and a correlation by color map (B) of the evaluated variables.

Legend: WL = Weight Loss; F = Firmness; ΔE Pulp = Color Difference for the pulp; ΔE Peel = Color Difference for the peel; SS = Soluble Solids; TA= Titratable acidity; SS/TA = SS/TA Ratio; AA = Ascorbic acid; CI = Color index; CU = Color Uniformity; ID = Incidence of Decay; PI = Purchase Intention; GA = General Appearance.

In turn, PC 2 discriminated 19.3% of the variance, forming two groups. One group included fruits coated with S2% and S2% + 0.45% EO, while the other group included fruits with S2% + 0.15% and S2% + 0.30% EO due mainly to the higher scores of GA and PI, in addition to lower ID of papaya of the latter. Azerêdo et al. (2016), in mango coated with cassava starch and fennel EO kept refrigerated and transferred to room conditions, reported similar behavior based on GA and PI, as well as lower ID. The groupings formed here clearly discriminate against the superiorities of S2% + 0.30% EO. in maintaining the quality of the fruits (Figure 5 A).

Through a correlation analysis among the physical, physical-chemical and sensory data (Figure 5B), a strong positive correlation was observed among most variables except for the strong negative correlation of firmness with most variables. The levels of soluble solids (SS), ascorbic acid (AA) and CI, showed a negative correlation with firmness (F) and color difference of the peel (ΔE Peel (-0.83). With respect to the other variables, there was a correlation positive, with values close to 1. The sensory attributes and the color index showed a strong positive correlation with all variables, excepted by the fruit firmness. As also observed in herein for papaya 'Sunrise Solo', Rodrigues et al. (2018), in 'Paluma' guavas coated with jackfruit starch, also reported a negative correlation of firmness with CI, indicating that as the yellow color evolves, the fruit softens during ripening (Zerpa-Catanho et al., 2017).

Conclusions

Papaya coated with S2% + 0.30% EO showed a delay in color evolution, lower weight loss, maintained the levels of soluble solids and ascorbic acid, in addition to reducing the incidence of decay and maintain de general appearance and increasing the purchase intention, thus increasing postharvest life in 4 days as related to control fruits.

All together, the use of 2% starch coating added with 0.30% ginger essential oil is a viable, sustainable and cost-effective alternative for maintaining the quality and adding value to 'Sunrise solo' papaya as a clean technology.

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